Allasia, Daniel; Pachaly, Robson; Tassi, Rutineia; Goes Vasconcelos, Jose; Hodges, Ben R.; Dickinson, Robert

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CHALLENGES OF MODELING STORMWATER TRANSIENTS IN DEVELOPING COUNTRIES

BY DANIEL ALLASIA, ROBSON PACHALY, RUTINEIA TASSI, JOSE GOES VASCONCELOS, BEN R HODGES & ROBERT E DICKINSON

The rapid urbanization of developing countries has increased population densities and led to a new group of "mega-cities." This growth has often occurred without adequate planning, resulting in a range of problems including increased flood frequency due to inadequate stormwater infrastructure [1]. Such problems cascade into direct impacts on both people and the economy. For example, some cities in Brazil experience problems caused by inefficient urban stormwater facilities – with both undersized and oversized segments connected in any given system due to unplanned piecewise expansion.

Older segments may have obstacles (e.g., Figure 1) that cannot be accounted for using any standard equations and are poorly documented. The funding to correctly "right-size" the existing stormwater infrastructure is limited. Requests for such funding must compete with those for addressing other urban needs. Consequently, engineers must be creative in developing approaches to improve stormwater management and be aware that existing infrastructure might not follow design standards. This situation has even more serious implications when stormwater systems receive inflows from strong convective storms causing significant hydraulic transients.

Upgrades of stormwater facilities in developing countries are often designed with very limited data. For instance, the existing system plans may be non-existent or miss key information, the design rainfall criteria may not be specified, watershed monitoring data is usually sparse, and pre-development conditions are poorly documented. Nevertheless, new system additions must be blended with the existing infrastructure, increasing its already complex topology and presenting a system that is far from the "best practices" that would be used when designing on a clean slate. Ill-advised situations can arise in the course of adding new structures to an existing system, such as conduit cross-sectional area contractions, poorly aligned expansions, unplanned shafts, short conduits, and insufficient inlets. In addition, maintenance practices may be poor or non-existent, leading to sediment and litter accumulation in inlets and conduits (Figure 2), thus triggering grade flooding and/or conveyance loss. The resulting systems do not readily propagate a stormwater impulse through the network in the way envisioned in our standard design practices. Sewer transients can lead to damaging and dangerous conditions, ranging from destruction of streets to geysers (Figure 3). Understanding the response of these unorthodox systems to transients is critical to finding designs that efficiently reduce choking points and can thereby reduce flooding.


Figure 1. Unplanned obstacles in the collection systems' cross-section in Brazil (source: SUDECAP).


Figure 2. Sediment and litter accumulation in collection systems.

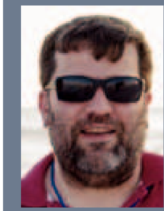

Figure 3. Geyser at a manhole in Southern Brazil.

Accurate and reliable hydraulic models are needed to revise the designs of these complex urban stormwater systems. Due to funding limitations, freely available models such as HEC-RAS or SWMM are usually selected, even though these models have not been designed to simulate hydraulic transients in closed conduits. Unfortunately, the same funding problems typically prevent the collection of an adequate data set for model calibration/validation and may also limit the training available for model users. In the hands of properly skeptical engineers, such free hydraulic/hydrological modeling tools can be valuable despite limited data, but the user-friendly interfaces and robustness of the latest model versions can lead less-experienced practitioners into trouble. Engineers without enough hydraulic training may develop a false perception of the model reliability and its boundaries of effectiveness – particularly where the complex hydraulics phenomena are involved. For example, SWMM unsteady formulation solves the flow conditions in a network of links and nodes through the Saint-Venant equations [3]. This solution well-represents typical stormwater conditions; however, for rapid inflow conditions associated with extreme inflows or complex system geometries, SWMM typically underestimates surges, under-represents sudden changes in sewer flow conditions, and yields significant flow continuity errors accompanied by numerical instabilities [2], [4].

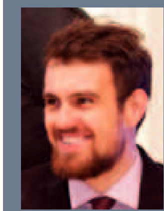
In turn, HEC-RAS incorporates a Mixed Flow Regime option based on the Local Partial Inertia Technique [5]. The LPI method systematically reduces inertial terms in the Saint-Venant equations diminishing the numerical instabilities in the simulation. However, this option introduces simplifications in simulation and should be utilized only after determining that a mixed flow situation exists, which requires judgment from the modeler [6].

Arguably, the low-cost adaptation of the stormwater systems in developing countries is one of the most challenging stormwater infrastructure problems we face, and yet it does not draw the attention and expertise it needs. As cities continue to grow under the pressure of climate change, the need for stormwater systems (and stormwater engineers) that effectively handle transients caused by rapidly changing flows during strong convective storms becomes more pressing.

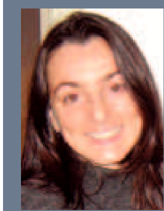
Comprehensive education of engineers and decision-makers and other stakeholders that adequately explains the usefulness and limitations of freely available models should be a priority as well as robust investment in data collection, analytics, and smarter application of free tools that can help practitioners to cope with hydraulic transients in sewer systems. Using SWMM as an example, these tools can range from analysis tools [7], model's plugins that recommend models setups based on expected dynamic flow conditions, [2] or even more complex numerical models [9].



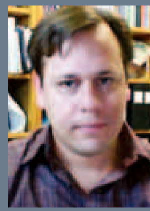
Daniel Allasia earned his Bachelor in Hydraulic Engineering from UNNE, Argentina, in 2000. He then went on to earn his MSc and Ph.D. in Water Resources and Sanitation, both from the Federal University of Rio Grande do Sul, Brazil (2003, and 2008). He is a Professor of the Federal University of Santa Maria, Brazil since 2009 researching LID, extreme flows and surges in urban water systems with a focus on scarce data regions. Associate editor of the Journal of Hydrologic Engineering (ASCE) and J. of Water Management Modelling (CHI. He has been awarded as Outstanding Reviewer (2018) and Best Case Study (2013) of the Journal of Hydrologic Engineering in 2013 of the American Society of Civil Engineers (ASCE).



Robson Leo Pachaly is a current Ph.D. student and Teaching Assistant in Civil Engineering at Auburn University, USA. He holds a bachelor's degree in Sanitary and Environmental Engineering and a master's degree in Environmental Engineering, both degrees obtained at the University of Santa Maria, Brazil. He developed open-source plugins for QGIS that aided the acquisition of hydrological data in Brazil and ReSWMM software that improves the hydraulic computations of the EPA Stormwater Management Model (SWMM).

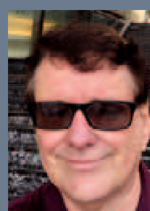


Rutineia Tassi earned her bachelor's in Civil Engineering from the Federal University of Rio Grande do Sul (UFRSG), Brazil, in 1999. She earned her MSc and Ph.D. in Water Resources and Sanitation, both from UFRGS, Brazil (2002, and 2008). She was Professor at Federal University of Rio Grande from 2004 until 2008, and since 2009 is Professor at Federal University of Santa Maria, Brazil. A reviewer of several journals, her researches focuses on hydrological modeling, surface hydrology, urban water including LID. She is a member of the Urban Water Committee of the Water Resources Brazilian Association.



José Goes Vasconcelos is the leader of Hydraulic Research Group at Auburn University, publishing experimental and numerical investigation on unsteady flows in closed conduits, air-water interactions, cavitation effects (TPAcav), extreme flows and surges in urban water systems. His SHAFT model was used in the simulation of large below-grade stormwater storage systems in Washington, DC; London, UK; St. Louis, MO; among other systems. Associate editor in the Journal of Hydraulic Engineering (ASCE), J. of Water Management Modeling (CHI), reviewer for several publications related to unsteady hydraulics and two-phase flows. He is chair of the ASCE EWRI Hydraulic Structures Committee, and the ASCE EWRI Task Committee "Two-phase Flows in Urban Water Systems."

Ben Hodges was educated at the U.S. Merchant Marine Academy (BS), the George Washington University (MS), Stanford University (Ph.D.) and the University of Western Australia (post-doc). He has taught and conducted research at the University of Texas at Austin since the year 2000. His research focuses on water flow and transport behaviour in lakes, rivers, estuaries, and across the urban landscape using advanced 1D, 2D, and 3D models. He is the Principal Investigator for the National Center for Infrastructure Modeling and Management, a 5-year project funded by the US EPA to develop the next generation models of water distribution systems and stormwater runoff management.



Robert Dickinson is the Innovyze Product Sector Leader for ESRI Products InfoSWMM/InfoSewer; Supports InfoWorks_ICM, ICM_SWMM, XPSWMM, SWMM5, Center for Infrastructure Management and Modeling (CIMM); Founder SWMM5.ORG. In the past, he was a Co-Developer of EPA SWMM 3,4,5+, XPSWMM.

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